

Different Postharvest Treatments and Storage Conditions for Shelf-life Enhancement and Quality Retention of Litchi

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Received: November 24, 2023

Accepted: March 11, 2024

Published: March 15, 2024

Citation: Devi S, Mishra P, Saini P, Yadav AK, Kumar T, et al. 2024. Different Postharvest Treatments and Storage Conditions for Shelf-life Enhancement and Quality Retention of Litchi. *J Food Chem Nanotechnol* 10(S1): S117-S123.

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Abstract

Litchi (*Litchi chinensis* Sonn.) is a highly perishable and delicate fruit. Browning of pericarp and physiological loss in weight are the paramount problems associated with storage of litchi. This study was carried out to extend the shelf-life of litchi by applying different postharvest treatments and to evaluate the effects of these treatments on physiological and physicochemical characteristics of litchi during storage. The different treatments given to the fruits were - control (untreated), precooling, hot water treatment (HWT) of 55 °C for 12 min, HWT + 1.5% nitric acid (HNO₃) for 10 min, HWT + 1.5% HNO₃ for 10 min + 2% calcium chloride (CaCl₂) for 15 min, and HWT + 1.5% HNO₃ for 10 min + 2% CaCl₂ for 30 min. The treated fruits were packaged in paper boxes (4% ventilation) and 4% perforated polyethylene bags (165 gauze) and stored in cold condition (4 - 5 °C, 85 - 90% relative humidity). Sulfite (300 mg sulfur/kg fruits) treated litchi fruits and untreated fruits (control) were also stored in the similar fashion for comparison. The various quality parameters of the fruits viz., physiological loss in weight (PLW), browning index, spoilage, pH, total soluble solids (TSS), ascorbic acid, and acidity were determined. The results indicated that the litchi fruits treated by HWT + 1.5% HNO₃ for 10 min + 2% CaCl₂ for 15 min and stored in cold condition were acceptable even after 28th day of storage. The effect of packaging material was not significant during cold storage. It is concluded that this treatment may successfully be employed as an alternative to sulfitation for enhancement of shelf-life and maximum retention of quality of litchi fruits.

Keywords

Litchi, Hot water treatment, Chemical dip, Physiological loss in weight, Browning

Introduction

Litchi is a subtropical and non-climacteric stone fruit. The fruits may vary in shape from round to ovoid to beautiful heart-shaped surrounded by attractive pink-red leathery pericarp. It is well known for its exotic flavor and succulent aril. The fruit can be enjoyed raw and can also be taken in the form of juice, wine, jelly, dried litchi, canned litchi, and frozen litchi [1, 2]. India retains second position in the world litchi production next to China. More than 750000 metric tons of litchi is annually produced from about 80000 hectares of area in India. The rank of litchi among all fruit crops in India is seventh in cultivated area, ninth in production, and sixth in value [3]. Litchi is packed with high nutritional value and numerous health benefits. The fruit contains a good number of vitamins

(B1, B2, B3, B6, C, E, K), carotenoids, minerals (potassium, copper, iron, magnesium, phosphorus, calcium, sodium, zinc, manganese, and selenium), and polyphenols [4, 5]. In general, litchi pericarp and seeds are considered inedible and dumped as waste products during processing; however, they are good sources of flavonoids [6]. The fruits have hypoglycemic, anticancer, antibacterial, anti-hyperlipidemic, and antiplatelet benefits [6-8]. Litchi has also been reported to exhibit some medicinal properties like protection against oxidative stress, treatment of hyper-uricemia, reduction of fatigue and visceral fats [9-12].

Litchi is a highly perishable fruit. Within 24 - 48 h after harvesting of litchi fruit, its alluring red pericarp turns to unpleasant brown color and 7 - 11% of weight is lost in ambient condition which reduces marketability of fruit to great extent [13]. Nowadays, the pericarp browning in litchi is being controlled using the combination of low temperature, high humidity, and plastic packaging. Sulfur dioxide fumigation as an alternative treatment to inhibit enzymatic activity has also been reported to be practiced commercially. However, the use of sulfite does have some disadvantages; especially the side effects on the health of the processing plant workers and the consumers [14]. On that account, the Food and Drug Administration has partly restricted the use of sulfites [3]. Hence, it is essentially required to find a safe and economically viable alternative postharvest technique to control the browning and maintaining the overall quality of litchi fruit. The goal of this study was to enhance the shelf-life of litchi fruits by applying different combinations of thermal and chemical treatments and to evaluate the effects of the applied treatments on their quality during the storage period.

Materials and Methods

Raw materials

The litchi (*L. chinensis* Sonn.) cultivar Rose Scented was selected for this investigation and the ripe fruits were collected from the Horticulture Research Center, Pattarchatta, G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand, India) during the peak season (June). In this study, only AR grade chemicals and reagents were used for all treatments and physicochemical analysis.

Sample preparation

The litchi fruits after harvesting were collected in cloth bags and taken to the laboratory preventing from any physical and mechanical damage during handling and transportation. Uniform sized ripe fruits free from blemishes, infestation, and physical injury were selected. Then, the fruits were destalked leaving about 2 mm pedicel using a pair of scissors and cleaned with running water.

Treatments to litchi fruits

The selected litchi fruits were subjected to different treatments, namely, precooling, HWT, HNO₃ dip, CaCl₂ dip, and different combinations of these with different time. Then the treated samples were stored in ambient condition for 4 days. The best result treatment was further compared with control

Table 1: Post-harvest treatments subjected to litchi fruits.

| Notation | Treatments |
|----------------|--|
| T ₁ | Control |
| T ₂ | Precooling |
| T ₃ | HWT |
| T ₄ | HWT + 1.5% HNO ₃ for 10 min |
| T ₅ | HWT + 1.5% HNO ₃ for 10 min + 2% CaCl ₂ for 15 min |
| T ₆ | HWT + 1.5% HNO ₃ for 10 min + 2% CaCl ₂ for 30 min |

and sulfite treatment storing in polyethylene bags and paper boxes in cold condition for 28 days. The samples were analyzed for changes in physiological characteristics (PLW, browning index, and spoilage) and physicochemical properties (pH, TSS, ascorbic acid, and acidity). The details of postharvest treatments subjected to litchi fruits are in the present study in table 1.

HWT

Litchi fruits were steeped in a water bath (UNILAB) at 55 ± 1 °C for 12 min, after which they were cooled by dipping them in cold water (15 ± 1 °C) for 10 min and then chemically treated.

Sulfite treatment

Sulfite treatment of litchi was done by fumigation of sulfur dioxide gas in a closed chamber (14 × 14 × 14 cm) for 45 min. Fruits were placed on perforated aluminum trays in the chamber and filled with sulfur dioxide gas by burning sulfur powder (300 mg per kg of fruits).

Determination of physiological characteristics

Ten fruits taken randomly were weighed and the average weight was calculated. PLW, in terms of percentage, was measured by dividing the difference of initial and final weight of fruits after specific days of storage by the initial weight of fruits [15]. Browning index was determined by adding the multiplication of browning scale and the percentage of fruits belonging to each category [16]. Spoilage percentage was calculated by counting the number of spoiled fruits considered unhealthy for consumption out of total fruits [15]. All the measurement was done at the interval of 2 days for ambient storage and 7 days for cold storage.

Determination of physicochemical properties

pH of the samples was determined with a digital pH meter. The TSS of the samples was determined using digital refractometer and expressed in °Brix. The percentage acidity was determined by titration of a known quantity of aliquot against 0.1 N sodium hydroxide using phenolphthalein indicator. The ascorbic acid (mg/100 g of juice) content was determined by titration using 2,6-dichlorophenol indophenol indicator. All these analyses were performed according to the methods described by the Association of the Official Analytical Chemist [17].

Statistical analysis

The experiment was laid out in a completely randomized

design and the statistical analysis was performed according to the method given by Snedecor and Cochran [18]. The differences between the means were tested by analysis of variance at the significance level of 5%.

Results and Discussion

Changes in physiological characteristics of litchi stored in ambient condition

Result showed that the PLW was the lowest (4.54%) for T_5 treatment while the highest (5.37%) for T_1 (control) was during 4 days of ambient storage of litchi fruits (Figure 1). The treatment T_5 also showed the minimum PLW of 1.17%, 3.64% and 4.54% after 0th, 2nd and 4th day of storage, respectively.

The results indicated that the PLW of litchi increased significantly for all treatments, storage temperatures and types of packaging material. PLW of litchi during storage is mainly due to water loss from the fruit which reduces the weight and the quality of produce. It has been reported that the PLW of litchi may range from 3% to >50%, depending on the cultivator, treatment, packaging, and storage conditions [19]. The results of this study were like the findings of Chakraborty and Banik [20]. It was found that the PLW in litchi fruits was least in T_5 treatment (HWT + 1.5% HNO_3 for 10 min + 2% $CaCl_2$ for 15 min). This may be due to application of an effective amount of chemicals and treatment time which slowed the ripening of the fruits [21-23].

Browning of fruit skin is the first and foremost visual sign of quality deterioration. The effects of different treatments on browning indices of the litchi samples during storage period are presented in figure 2. In this study, browning index increased significantly with storage period. It was found that the browning indices of T_4 and T_5 treated samples were minimal and significantly lower than that of the other treatments. The browning indices of T_4 and T_5 treated samples were the same during the entire period of storage. The maximum browning index (424.33) was observed for T_3 (HWT).

Many reasons have been cited in earlier pieces of literature for the development of fruit browning. These include increase in pH, decrease in anthocyanins due to enzymatic activity of polyphenol oxidase or peroxidase, phenolics oxidation, desiccation and microcracking [16, 24, 25]. Browning of pericarp does not excessively affect the quality of litchi arils but diminishes the consumers' predilection for the fruit. The peroxidase activity that causes the browning of fruits may be effectively inhibited by acid dip after the HWT [16]. Similar findings reported by Saengnil et al. [23] and Atinut et al. [26] concluded that HWT (98 °C for 30 s) followed by oxalic acid (10%) dip was highly efficient for inactivation of polyphenol oxidase and peroxidase enzymes.

The least spoilage (65%) was obtained for T_5 treatment followed by T_4 treatment with 75% spoilage (Figure 3). The highest spoilage of 88.75% was observed for HWT (T_3) during the entire period of storage. There are several postharvest factors responsible for the fruit's spoilage. Transportation, handling, and storage are such unit operations in which the

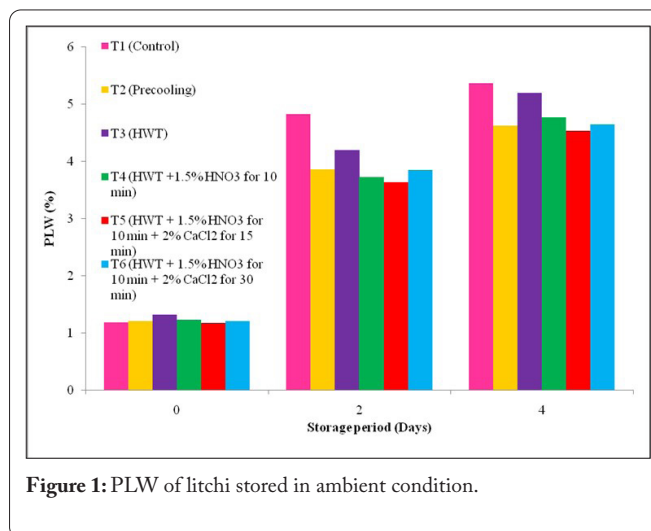


Figure 1: PLW of litchi stored in ambient condition.

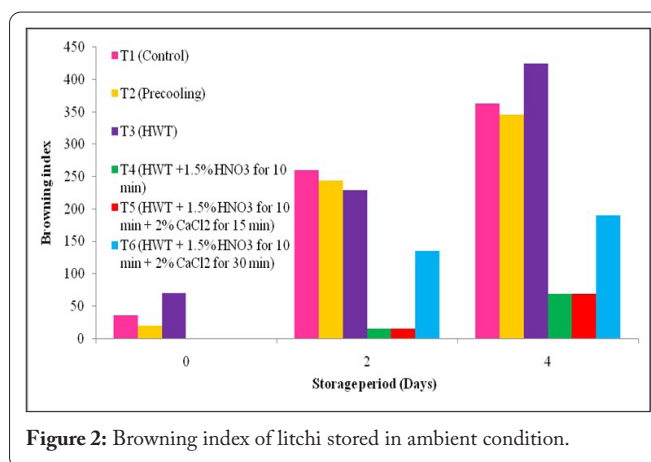


Figure 2: Browning index of litchi stored in ambient condition.

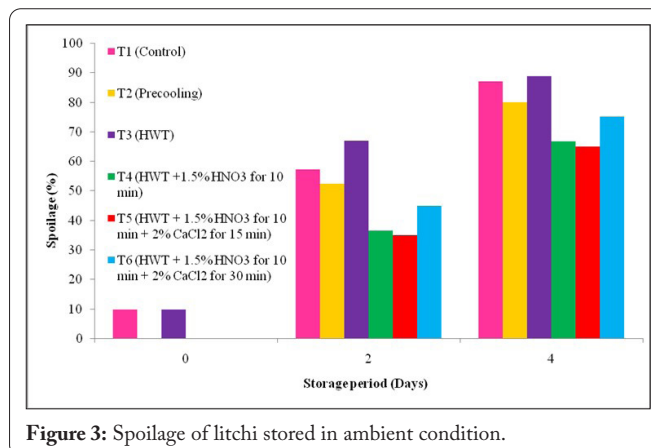


Figure 3: Spoilage of litchi stored in ambient condition.

fruits are most likely to deteriorate due to mechanical injury, rot, and browning. The present study showed that the maximum spoilage occurred in samples treated with hot water alone, but HWT with chemical treatment effectively controlled the spoilage. It may be due to the fungicidal and fungistatic effects of hot water and chemicals applied by killing the fungal pathogens and making them difficult to grow on the surface of fruits. The findings of this study are well supported by Fallik et al. [27] in apples and Lichter et al. [28] in litchi.

Effects of different treatments on pH of the samples were found to be 4.22 - 4.80 at the end of storage period (Figure 4).

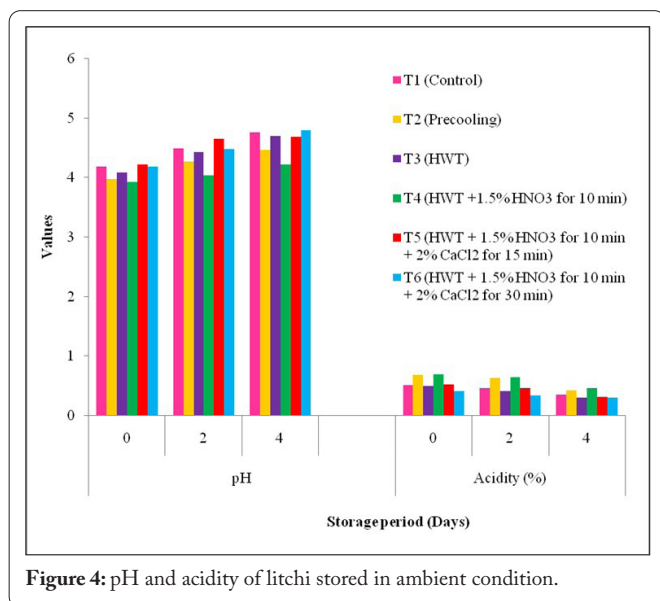


Figure 4: pH and acidity of litchi stored in ambient condition.

The pH value was lowest (4.22) for T₄ treated samples while the highest (4.80) for T₆ treated samples. The minimum increase in the pH of 7.38% for T₄ treatment whereas the maximum increase of 14.56% for T₆ (HWT + 1.5% HNO₃ for 10 min + 2% CaCl₂ for 30 min) was observed. It was found that treatments, storage period and their interactions significantly affected the pH of the fruits. The pH of litchi aril increased with the progress of storage. This increase in pH may be due to a decrease in acidity. Similar findings were also reported by earlier investigators [29-31].

Results obtained as the effects of various treatments on the acidity of samples stored in ambient condition are shown in figure 4. It was found that the variation in the acidity levels immediately after the treatments was very high (0.42 - 0.70%), which had reduced to 0.31 - 0.46% by the end of the storage period. Acidity of all treated samples decreased during the storage period. The decrease in the acidity was maximum (58%) for T₃ treatment and minimum (26.19%) for T₆ treatment. On the last day of the storage period, the lowest value of acidity (0.31%) was recorded for T₃ and T₆, while the highest value (0.46%) was recorded for T₄. Regardless of treatments applied, the acidity of litchi decreased throughout storage. The decline in acidity may be due to the conversion of organic acids into sugars. The result of this experiment was like that reported by Kumar [32]. It was also found that the effects of treatments, storage time, and their interactions on the acidity of fruits were statistically significant.

The changes in TSS content of the samples subjected to different treatments during ambient storage are presented in figure 5. TSS content initially ranged from 15.80 - 16.73 °Brix which increased to 18.07 - 18.87 °Brix by the end of the storage period. The maximum TSS (18.87 °Brix) was observed for the samples treated by T₅ and the minimum TSS (18.07 °Brix) was observed for the samples treated by T₄. The increase in TSS was the least for pre-cooled samples (T₂) while the highest (14.70%) in for the control sample. An increase in TSS of litchi during storage may be associated with water loss in fruits and hydrolysis of sucrose to invert sugars [33, 34]. The

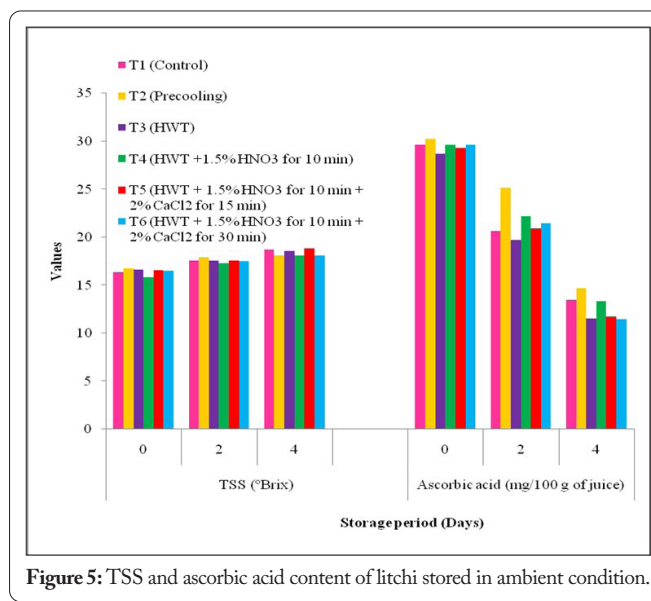


Figure 5: TSS and ascorbic acid content of litchi stored in ambient condition.

treatments, storage time and their interactions significantly affected the TSS content of the fruits.

Figure 5 shows the variation in ascorbic acid content of the samples during storage. Initially, the amount of ascorbic acid ranged from 28.72 to 30.27 mg/100 g juice which reduced to 11.46 - 14.66 mg/100 g juice by the end of the storage period. The minimum loss of ascorbic acid was 51.57% obtained for pre-cooled samples (T₂) while the maximum loss was 61.34% obtained for T₆ treated samples. In this study, ascorbic acid of litchi fruits reduced more than 50% throughout the storage period regardless of applied treatments. This decrease in ascorbic acid content may be due to its high sensitivity to light, oxygen, and temperature [35, 36]. The effects of treatments, storage period, and interactions on ascorbic acid content were statistically significant.

Physiological changes in litchi stored in cold condition

It was observed that the T₁ and T₂ treated samples had been spoiled after 7 and 14 days of storage, respectively, and only the T₃ treated samples were in good condition at the end of storage period. Therefore, the data related T₁ and T₂ were not taken after 7 and 14 days of storage, respectively. The changes in PLW during cold storage are shown in figure 6. For the samples treated by T₁ (Control), T₂ (Sulfitation) and T₃ (HWT + 1.5% HNO₃ for 10 min + 2% CaCl₂ for 15 min), the minimum loss in weight was 7.19% with polyethylene bags and 7.21% with paper boxes packaging at the end of the storage period. The PLW may be due to water loss from the fruit during the storage period. It has been also reported that the PLW of litchi may range from 3% to >50%, depending on the cultivator, treatment, packaging, and storage conditions [19].

The effects of different treatments on browning indices of the litchi samples stored in cold conditions are presented in figure 7. In this study, browning index increased significantly with storage period. It was observed that there was no browning up to 21 days in all the samples treated with T₃ and up to 7 days in the samples treated with T₂ (sulfation) packed in paper boxes. Browning was started in all control samples and

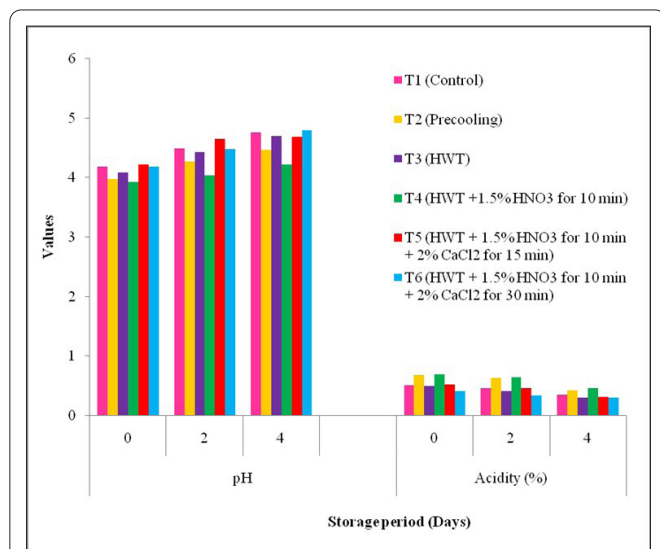


Figure 6: PLW of litchi stored in cold condition.

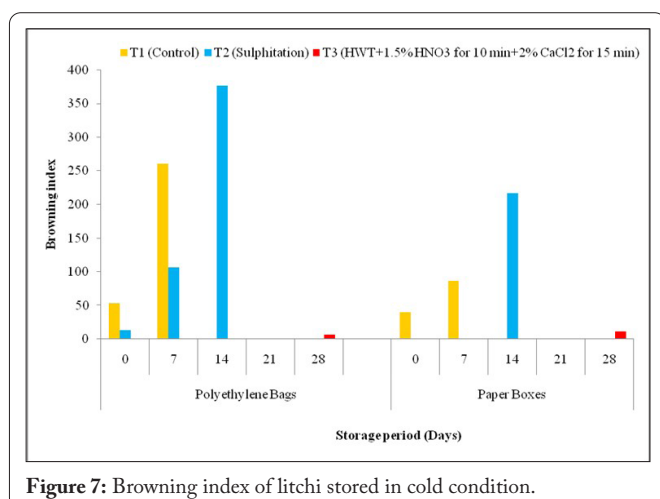


Figure 7: Browning index of litchi stored in cold condition.

sulfited samples packed in polyethylene bags right from the first day. Browning index of control and sulfited samples in both packaging materials was maximum after 7 and 14 days of storage, respectively. On the last day of storage, the lowest browning index was 6.67 which was observed in T₃ treated samples stored in polyethylene bags. Browning of fruits is a natural phenomenon which may be due to increase in pH, decrease in anthocyanins due to enzymatic activity of polyphenol oxidase or peroxidase, phenolics oxidation, desiccation and microcracking [16, 24, 25]. The peroxidase activity that causes the browning of fruits may be effectively inhibited by acid dip after the hot water treatment [16]. Similar findings reported by Saengnil et al. [23] and Atinut et al. [26] concluded that hot water treatment (98 °C for 30 s) followed by oxalic acid (10%) dip was highly efficient for inactivation of polyphenol oxidase and peroxidase enzymes. The effects of treatments, types of packaging material, storage time and their interactions on the browning of litchi were statistically significant.

The percentage spoilage of the samples stored in cold condition is shown in figure 8. T₃ treated samples stored in both types of packaging material were not spoiled up to 21 days. In contrast, T₁ and T₂ treated samples began to deteriorate from

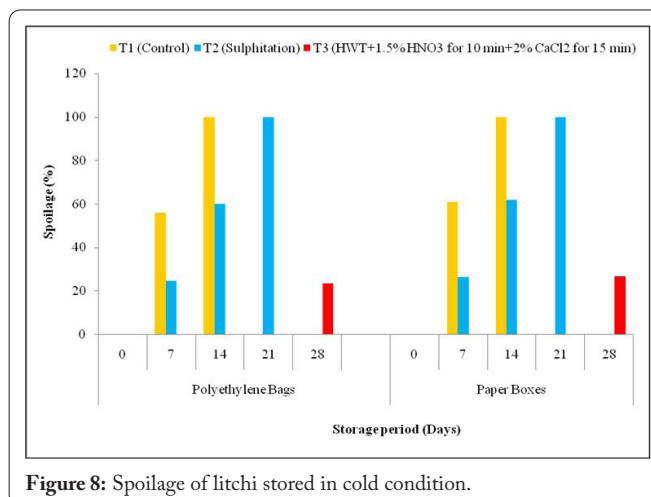


Figure 8: Spoilage of litchi stored in cold condition.

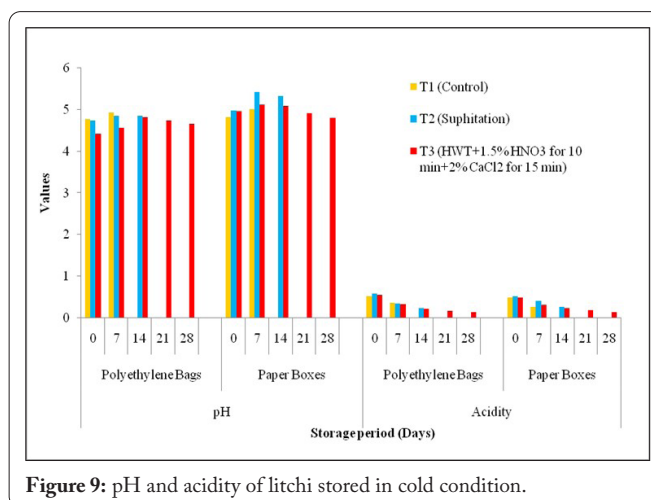


Figure 9: pH and acidity of litchi stored in cold condition.

the 7th day of storage regardless of the type of packaging material. It was observed that the fruits spoilage was less in polyethylene bags than paper boxes for all treatments. The present study showed that the maximum spoilage occurred in the untreated (control) and sulfite treated samples, while HWT with chemical treatment effectively controlled the spoilage. It may be due to the fungicidal and fungistatic effects of hot water and chemicals applied by killing the fungal pathogens and making them difficult to grow on the surface of fruits. The findings of this study are well supported by Fallik et al. [27] and Lichter et al. [28] in litchi. It was also found that there were significant effects of treatments, types of packaging material, storage time and their interactions on spoilage of the fruits.

Data given in figure 9 pertained to the changes in pH of the samples due to application of different treatments, packaging materials and cold storage. It was observed that pH of the samples increased up to 7th day for all treatments. A slight increase in pH of T₃ treated samples was recorded till 14 days after which it decreased significantly by the end of storage period, regardless of the packaging material. The pH of T₃ treated samples packed in polyethylene bags increased from 4.43 to 4.82 in 14 days which decreased to 4.67 as storage progressed. Similarly, when packed in paper boxes, the pH increased from 4.97 to 5.43 and decreased to 4.81. The findings of this study were like those reported by prior investigators [29-31]. Treat-

ments, types of packaging material, storage time and their interactions significantly affected the pH of the fruits.

The effects of different treatments, types of packaging and storage period on the acidity of samples stored in cold conditions are presented in figure 9. Results revealed that acidity decreased gradually with an increase in storage period for all treatments. Initially, the acidity of the samples was in the range of 0.50 - 0.59% which reduced to 0.27 - 0.37% (T_1), 0.24 - 0.27% (T_2) and 0.14 - 0.15% (T_3). The decline in acidity during storage may be due to the conversion of organic acids into sugars. The result of this experiment was similar to that reported by Kumar [32]. The effects of treatments, types of packaging material, storage time, and their interactions on acidity of litchi were statistically insignificant.

The changes in TSS content of the samples subjected to different treatments and packaging materials during the cold storage are presented in figure 10. It was observed that the range of TSS value increased from 17.07 - 18.67 °Brix to 17.60 - 19.67 °Brix by the end of the storage period. The increase in the TSS content was minimum for T_3 treated samples (1.15%) packed in polyethylene bags and the maximum was for untreated fruits (6.61%) having the same type of packaging. This increase in TSS content during cold storage may be associated with water loss in fruits and hydrolysis of sucrose to invert sugars [33, 34]. The increase in TSS of litchi during storage at low temperature storage conditions might be associated with the hydrolysis of sucrose to invert sugars and dehydration of fruits [33, 34]. The treatments, packaging methods, storage period, and their interactions significantly affected the TSS content of litchi.

Figure 10 shows the variation in ascorbic acid content of the samples subjected to different treatments and packaging materials during cold storage. Initially, the range of ascorbic acid content varied was 29.95 - 32.98 mg/100 g which declined to 17.53 - 19.36 (T_1), 14.44 - 15.17 (T_2) and 2.85 - 3.56 mg/100 g (T_3). It was observed that the ascorbic acid of the fruits degraded throughout the storage period regardless of applied treatments. The degradation in ascorbic acid content during storage may be due to its high sensitivity to light, oxygen, and temperature [35, 36]. Results also revealed that the factors' individual and combined effects were statistically significant.

Conclusion

This research concluded that dip postharvest treatments may be successfully employed along with exploring suitable alternative technologies to replace sulfide dioxide fumigation, On basis of types of packaging, storage period and their effects on physicochemical characters, sensory evaluation, quality retention, and changes during storage of litchi fruit. It was found that chemical treatment with 1.5% HNO_3 for 10 min and 2% $CaCl_2$ for 15 min after dipped in HWT at 55 °C for 12 min was the most efficient method, for maintaining the quality of litchi fruit for long time when packed in polyethylene bags and stored at low temperature. The treated fruit by this method were found acceptable the longest 4 days at ambient condition and increase shelf-life and to maintain the

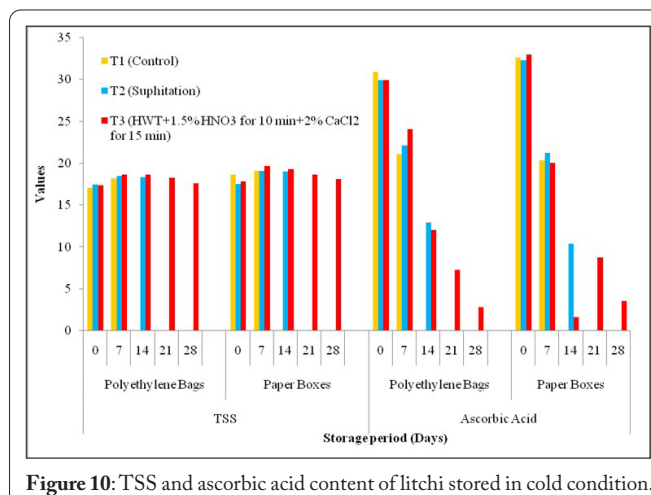


Figure 10: TSS and ascorbic acid content of litchi stored in cold condition.

quality after packaging in paper boxes and perforated polyethylene bags were kept on 27 days at cold conditions (4 - 5 °C, 85 - 90% relative humidity).

Acknowledgements

None.

Conflict of Interest

None.

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